agricultural ecology

Agricultural ecology is the application of ecological principles to agricultural systems. Since ECOLOGY has several frameworks of analysis, agricultural ecology can be studied from the perspective of energy flow, nutrient cycling, food webs, the interactions between populations of organisms, and the relations between organisms and their physical environment. The objective of agricultural ecology is to understand the conditions leading to sustainable, productive agriculture that has harmonious environmental impacts.

Natural Ecosystems

From an energy perspective, agriculture may be viewed as the capture and conversion of solar energy in the tissues of crops and livestock. Using the process of PHOTOSYNTHESIS, plants trap sunlight and combine its energy with carbon dioxide and water to form carbohydrates--energy-rich chemical compounds that provide the materials required to sustain both plant and animal life. Most of the energy captured by plants is used directly to sustain the plant, but a small fraction (termed the net primary productivity) is incorporated by the plant as growth--new biomass, or tissue, which is available as food for use by humans or other animals.

In natural ecosystems the energy contained in plant biomass is generally consumed by herbivores--animals that subsist on plant tissues--which are in turn consumed by predators, forming pathways known as food webs. Each organism in the pathway requires about 90 percent of its energy intake for its own maintenance, turning only about 10 percent into biomass. The rate of animal biomass production that can be sustained by an ecosystem is therefore much lower than that of plants: most of the energy they consume is dissipated and rendered unavailable for further use. Thus the presence of animal species in natural ecosystems reduces the quantity of food available for humans. In addition, some portion of the biomass of most ecosystems exists in forms unsuitable for human use. For these reasons relatively little energy is available for humans in natural ecosystems. It was necessary to develop agriculture, increasing the amount of available biomass, before human societies could increase their populations.

Ecosystems in Agriculture

The success of the development of agriculture is rooted in the alteration of natural ecosystems to enhance net production and reduce losses through consumption by other species. By increasing the biomass conversion efficiencies of livestock species and the usability of the resulting biomass, and by reducing losses to undesired pest species, relatively large quantities of crops and livestock may be raised on small parcels of land. This has been accomplished through the selective breeding of crop and livestock species; augmentation of the water and nutrient supplies available to plants through irrigation and fertilization; and the reduction or elimination of undesired plant and animal populations through cultivation and pest control.

In traditional agriculture net productivity was maintained through the development of farming systems that had many of the properties of natural ecosystems. Crop species with low susceptibility to pests were developed, animal and crop wastes were returned to the soil, and crops were rotated from year to year to ensure sustained soil fertility. These systems were generally transmitted from generation to generation through cultural beliefs and customs dictating the proper relationship between humans and the natural world.

While natural ecosystems provide relatively low yields to humans, they also provide many of the environmental services required to sustain their own productivity. Where the structure of these systems is disturbed through human intervention, the ability to sustain these services is generally lost, and productivity can be maintained only through the introduction of energy and materials from beyond the farm.

Consequences of Modern Agriculture

Modern agriculture has increasingly replaced the environmental services built into earlier agricultural systems with industrial inputs--machinery and synthetic FERTILIZER and pesticides. But the ecological costs of agricultural gains have been considerable. Industrial agriculture, for example, is heavily dependent on energy, large amounts of water, and other scarce natural resources. There is increasing evidence and concern that current agricultural practices will not be sustainable as natural resources become more scarce or more expensive.

Overreliance on chemical pesticides has had deleterious consequences. Pest populations are typically reduced immediately by the application of an effective pesticide, but the predators of the pest, which naturally regulate pest populations, have often been completely eliminated by pesticide application, while some members of the pest species survive to multiply freely in the absence of natural enemies. The short-term gains are thus frequently offset

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Overreliance on chemical pesticides has had unforeseen consequences. Pest populations are typically reduced immediately by the application of an effective pesticide, but the predators of the pest, which naturally regulate pest populations, have often been completely eliminated by pesticide application, while some members of the pest species survive to multiply freely in the absence of natural enemies. The short-term gains are thus frequently offset

by greater pest problems later in the growing season. Even when a particular pest is controlled, another insect, perhaps more destructive and difficult to eliminate, may move into the original pest's empty niche. To make matters worse, pest species frequently develop genetic resistance to particular pesticides. Thus pesticide misuse has often necessitated larger dosages of toxic, expensive chemical compounds.

Industrial agriculture has historically relied on intensive tilling and cultivation techniques, which leave the soil's surface unprotected for long periods of time, permitting erosion of topsoil. Although chemical fertilizers replace nutrients that are lost by the soil, they do little to replace the loss of the soil itself. New soil is built through the deposition and decomposition of plant material, a process substantially reduced by industrial agriculture. As a result, the ability of the soil to retain water and nutrients may deteriorate over time, reducing soil fertility.

The chemical inputs of industrial agriculture pollute the air, find their way into streams, and accumulate in groundwater supplies.

Finally, overreliance on IRRIGATION may lead to SALINIZATION, where salts contained in irrigation water accumulate in the soil as the water evaporates or is used by plants. Plants can tolerate salt in limited concentrations, but heavy soil deposits have rendered large areas of land infertile in both the industrialized and developing world.

Ecological Solutions

Existing agricultural practices can be modified through the adoption of an ecological approach emphasizing the maintenance of environmental services within agricultural systems. Energy- and resource-intensive inputs would be reduced, and natural ecological processes would be reintegrated into agricultural systems to enhance soil fertility and reduce pest infestations. For example, the use of integrated pest management--the cultivation of pest-resistant plant species, the maintenance of predator populations, reduced reliance on single crop, or "monoculture," systems, which are particularly susceptible to pest outbreaks--may be less costly and more ecologically sound in controlling pest populations than the routine use of pesticides. (See also PESTICIDES AND PEST CONTROL.)

Soil maintenance and regeneration can be accomplished using techniques such as covering the soil with crop residues, fertilization with animal wastes, and reduced tillage to cut erosion and accelerate new soil formation. Some plant species such as legumes and alfalfa increase soil nutrient concentrations, and successive plantings of these species can maintain soil fertility without extensive use of fertilizers.

The use of drip irrigation instead of more conventional techniques improves irrigation efficiency. As a result the heavy demands placed on water supplies and the energy needed to transport the water to arid and semiarid regions may be reduced substantially. Soil salinization is also less of a threat with lower water use.

Organic farming has demonstrated the validity of the ecological approach. Organic farmers may not grow as much corn or soybeans as their industrialized neighbors, but their costs are far lower, their soil generally richer, and their crops healthier.

Third World Ecologies

Many Third World nations have developed agricultural programs that will not be sustainable over the long run. The Brazilian government, for example, encouraged the establishment of agricultural settlements in the rain forests of the Amazon, on soils unsuitable for agriculture. Farming in most of the Amazon succeeds only through SLASH-AND-BURN cultivation, which is sustainable at low population levels but very destructive at higher levels, especially when combined with modern tools, government subsidies, and other devices designed to increase production.

Third World agricultural development should be rooted in an understanding of the ecology and culture of the country, so that food production works with, not against, nature. Only through properly designed programs that are sensitive to natural conditions can sustainable agricultural development be achieved.

Richard B. Norgaard

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